EXECUTIVE SUMMARY

The Grasslands in western Merced County were once part of an extensive, pristine wetland system that covered at least 4 million acres in the Central Valley of California. At that time the landscape was teeming with abundant wildlife. Large herbivores were common and wetland birds were so numerous that they blackened the skies. Beginning over 150 years ago, the onset of grazing and then farming gradually changed the landscape. Native perennial plant communities were replaced by exotic annuals before 1850, and large predators and grazing animals disappeared. As early settlers discovered the rich soils on the valley floor, development of a huge agricultural industry began. Key to the success of agriculture was an irrigation system to supply water for crop production coupled with an effective system for draining the irrigation water from fields.

As the landscape changed from a pristine setting to an agricultural system, native ecosystems were fragmented and the size of the remaining natural habitats gradually decreased. Conversion of the native systems to agricultural production accounted for much of the loss in size, but establishment of transportation and irrigation systems further fragmented the environment and disrupted migration corridors and movements of animals among remnant habitats. These same corridors allowed the rapid dispersal of exotic plants. Effective use of irrigation waters required land leveling and drainage systems to prevent salt concentration. These modifications further impacted the already greatly modified hydrology associated with the establishment of water storage and distribution facilities. Other changes associated with agriculture further impacted the quality and function of natural environments. The use of pesticides, herbicides and fertilizers degraded water quality. Intensive soil manipulations increased sedimentation, and irrigation water moving through some soils concentrated elements such as selenium that disrupted biological processes.

Because changes associated with agriculture had a profound effect on the size, distribution and quality of remnant natural habitats, many practices and habitats associated with agriculture become important for some wildlife. Grazing lands were used extensively by geese, cranes, and some shorebirds. Waste grains such as corn, wheat, barley and rice provided important sources of high energy foods readily consumed and digested by waterfowl and other granivorous birds. Nesting birds made use of agricultural fields such as alfalfa and wheat before harvest. Sites considered as waste areas by the agricultural community also were important for some wildlife. Sump areas for drain water and drainage ditches sometimes had borders of wetland vegetation that supported diverse wildlife aggregations.

Although the extensive disruption caused by agriculture reduced the numbers and changed the distribution of wild populations, the Central Valley continues to be one of the most important habitats for waterfowl on the North American continent even though habitats now cover less than 300,000 acres. About 60% of the wintering waterfowl in the Pacific Flyway use Central Valley habitats and about 65% of the North American pintail population use these wetland habitats. The largest contiguous block of remaining wetland habitat in the Central Valley is the San Joaquin Valley Grasslands. Of the remaining wetlands in the Central Valley, about 40% are clustered in the Grasslands between Merced and Los Banos along the San Joaquin River. This sizable area is of considerable importance because the variety of habitats are important to the maintenance of biodiversity on a national and international scale. Such habitat diversity is driven by differences in soils and hydrology between the East and West Grasslands. Thus, wetland habitats within the Grasslands represent many different hydrologies ranging from vernal pools to permanently flooded wetlands.

Central Valley habitats increasingly are being impacted by urban expansion. Cheaper land and housing in the Valley compared to the Bay area have attracted many people that are willing to commute long distances for employment. The population of Merced County is expected to grow from 180,000 in 1990 to 260,000 in the year 2000. As this population grows there will be multifaceted impacts that will further degrade both agricultural and remnant natural systems. As urbanization progresses, open space will continually disappear, fragmentation will increase and a host of factors with high potential to disrupt and degrade the functions and values of the Grassland ecosystem will be imminent. Expansion of transportation corridors in number and size will bring more fragmentation and increased air pollution. As areas of impermeable surfaces such as roofs, highways, and parking lots increase, runoff will be more rapid and of greater volume. Stormwater carries sediments and pollutants of many types. Free roaming pets are always in abundance near urbanized areas; their activities disrupt wildlife life history strategies and can result in direct mortality to wildlife. The juxtaposition of urban areas adjacent to natural environments has an insidious impact that gradually reduces the quality and functional area of these habitats. Such changes have been common place across the United States. The decrease in open space and associated fragmentation in conjunction with the effects of transportation, recreation, reduction in air and water quality, and general disturbance gradually modifies plant and animal communities. Monotypic plant communities will be more common. Exotic plant and animal species may increase while native populations disappear.

The Grassland ecosystem is a significant remnant of our natural heritage. Not only is this a unique parcel of a diminishing resource in the Central Valley and the state of California, but these wetland habitats are critical to the survival of migratory species that move across the North American continent and among continents during their annual cycle. Thus, further loss and degradation of this largest remnant wetland habitat in the Central Valley not only will have an important negative impact on local resident wildlife and plant communities, but also will negatively impact migrant animals that move to distant countries during their annual travels. For this reason, protection and appropriate management of this unique ecosystem is essential to assure preservation and to maintain productivity of this important natural heritage. Preservation of this system requires that fragmentation must stop and the area not decrease in size. Some agricultural land use practices will continue to provide important open space as well as important foods or habitats for wildlife. Protection of these agricultural lands from conversion to other uses should be an integral part of strategies aimed at protection of this important system.

Changes in land use require management to emulate historic water regimes that are tied to wetland productivity and life cycle events of wetland wildlife. Careful and timely manipulation of soil and water assure productivity and the biodiversity associated with diverse wetland systems.

This land use study has identified the perturbations that have effected this wetland ecosystem for the past 200 years. Available information clearly demonstrates the importance of strengthening the protection of the Grassland Wildlife Management Area to assure the long-term integrity of this important and unique habitat. Adequate open space must continue to exist in the future as part of protective measures that are essential to maintain the functions and values of this system for wildlife and humans. Additional information and a better understanding of interactions among perturbations must be generated before additional encroachments compromise the viability of this system forever.

INTRODUCTION

Man's first impact in the San Joaquin Valley dates back about 10,000 years to the arrival of immigrants that crossed the land bridge from Asia. At this time California had a rich fauna of wildlife that exploited diverse habitats in the mountains and valleys. The geomorphology of the Central Valley floor had a profound influence on the location, general topography, structure and function of these diverse habitats. The distribution, diversity, and abundance of plants and animals reflected the size and distribution of different habitats. The distribution of habitats in turn influenced the location of Native American populations. The extent Native Americans impacted wildlife populations is not fully known, but many suspect that their hunting skills were adequate to influence the distribution and size of large mammal populations (Burney 1993). However, native Americans differed from subsequent settlers because their way of life had little impact on the landforms or hydrologic regimes that controlled the dynamics of wetland habitats within the San Joaquin River floodplain.

When the Spanish arrived in the San Joaquin Valley in the 1700's, a wonderfully diverse and largely untouched ecosystem composed of interspersed wetland and upland habitats existed between the Coast Range and the Sierra Nevada. As an increasing number of settlers reached California in the 1800's, the potential for agriculture in the Valley was recognized and the first steps were taken to divert water for agricultural purposes.

Agricultural development reached a peak by the middle of the twentieth century. The modifications required for successful agriculture in this semiarid region had a dramatic influence on the landscape. Foremost among these changes were developments required to ensure a more consistent water supply across large portions of the Valley. Reservoirs were constructed to store water and extensive canal systems were built to transport water to farms. Such developments drastically affected the hydrology and water quality within the Valley. In addition, a transportation infrastructure that interconnected farms and communities was required to move equipment, supplies, and commodities, which further altered ecosystem function. As human populations continued to grow, more perturbations impacted an increasingly fragmented landscape. Open space decreased as the demands for housing, recreation, waste water treatment and other essential developments associated with urban and industrial expansion required more land. Continued growth and shifts in the human population in California remain an important influence on current land use. Projections for population growth within the Central Valley suggest a huge increase as more and more people seek affordable land and housing. These demands for living space and associated developments will continue to change the character of Merced County.

Collectively, these factors have had a profound influence on the size, distribution and function of pristine habitats that once provided wildlife populations with the seasonal necessities required for survival and reproduction. Some impacts are subtle and difficult to quantify (e.g., minor disruptions in landform) whereas others, such as changes in land use practices, have obvious results. This report documents the changes in land use in Western Merced County extending back more than 200 years. The implications of these impacts are described in relation to the location and types of activities associated with land use in the County and the potential or documented consequences to natural resource elements. The focus of the study identifies factors associated with the most recent changes in land use related to urban expansion, which will continue to occur in the Central Valley and specifically in western Merced County. The purpose of this document is not to promote the ideology that natural resource concerns be considered and preserved at the expense of economic growth and community development. Such a concept is no longer a viable option in today's society. Rather, the intent is to provide a factual basis that identifies the importance of the Grasslands as an integral component of a much larger landscape that is in imminent danger of being fragmented and disrupted to a greater extent. Further, it is imperative that all individuals and organizations be aware that irreparable damage to the land base likely will have devastating consequences to human populations. Thus, strategies must be implemented to assure that the value and function of natural systems remain viable in order to provide societal benefits and to protect open space for future generations to enjoy.

STUDY AREA

The focus of this report is on the land-use impacts within an area described as the Grassland Wildlife Management Area and surrounding lands within two miles of the management boundary (Fig. 1). This area, which encompasses 179,463 acres (Merced Data Special Services, Inc. 1993), includes the largest contiguous block of wetlands remaining in the Central Valley of California. A major wintering ground for migratory waterfowl and shorebirds of the Pacific Flyway, the Grasslands also provide habitat for a number of threatened and endangered species. The U.S. Fish and Wildlife Service recognizes the Central Valley (U.S. Fish and Wildlife Service 1986) as one of the most important wintering areas for waterfowl in the nation and the Western Hemisphere Shorebird Reserve Network has designated the Grasslands as an international reserve for migrant and wintering shorebirds. These important wetlands are the remnants of a wetland complex that historically extended throughout the Central Valley and composed part of a 4 million acre wetland system (U.S. Fish and Wildlife Service

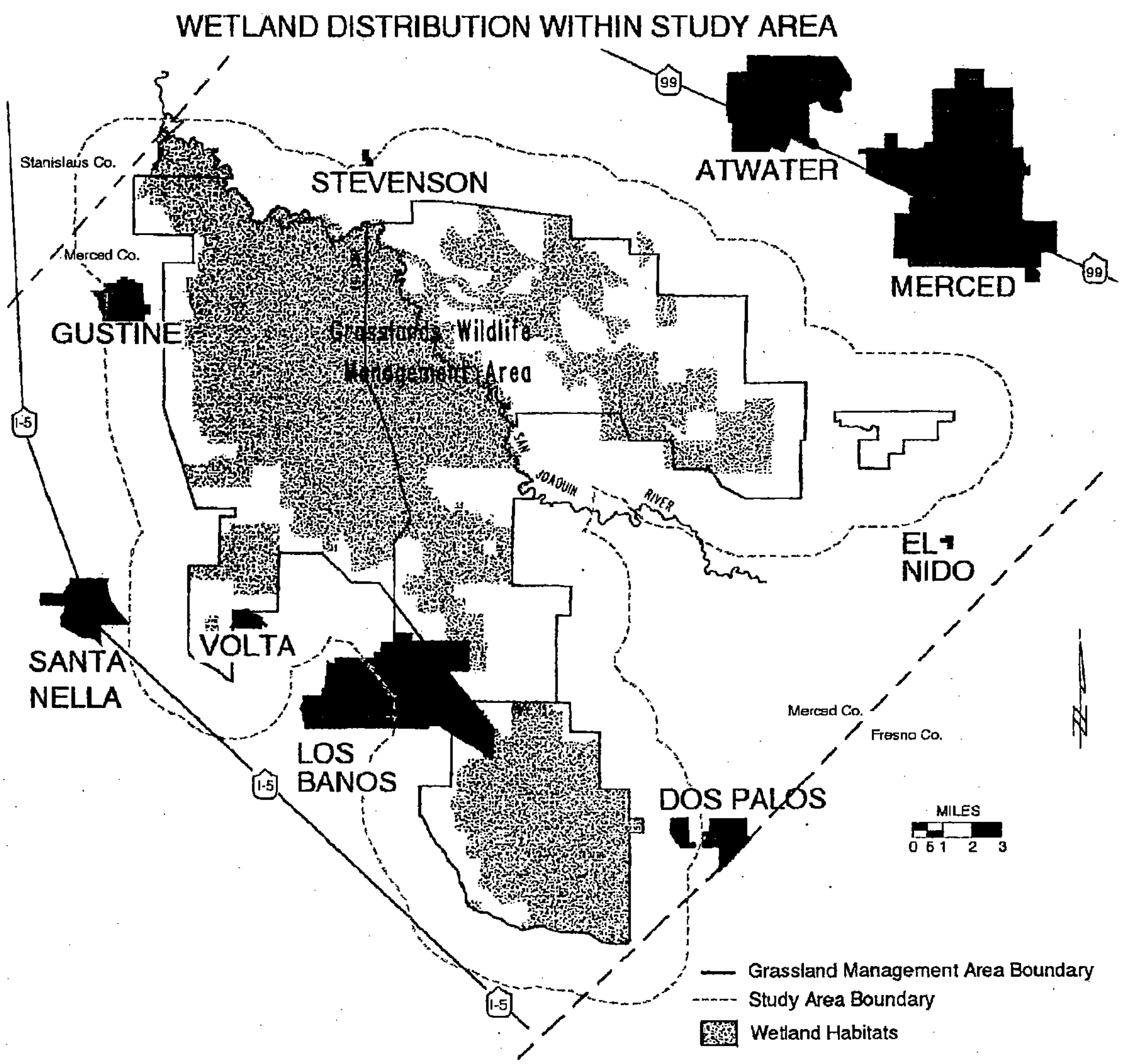

Fig. 1. Grasslands Study Area including a 2-mile perimeter surrounding the Grasslands Wildlife Management Area.

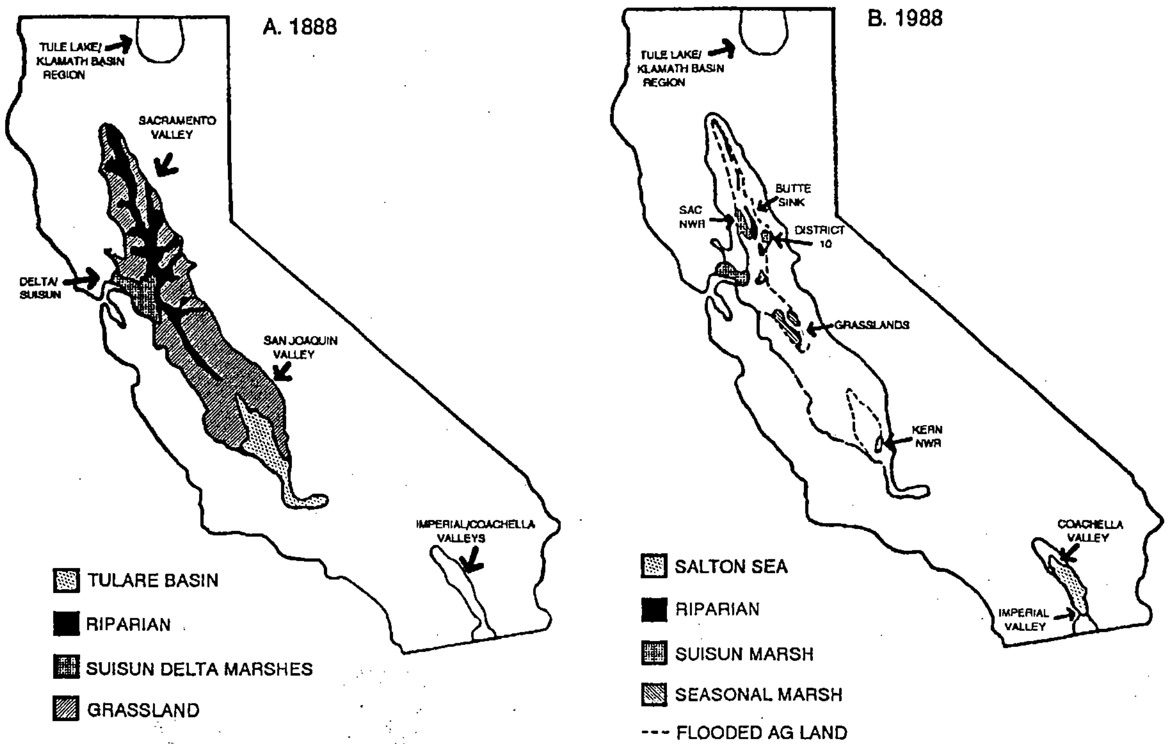

Fig. 2. Location and distribution of general habitat types in the Central Valley of California in 1888 (A) and the fragmentation of these contiguous habitats by 1988 (B).

1978, Fig. 2). Currently, only about 281,000 acres of wetland habitat remain in the entire Central Valley (U.S. Fish and Wildlife Service 1987). Land ownership within the Grassland study area is varied, consisting of federal, state, and private entities (Fig. 3). Habitat types also are diverse, including semipermanent and seasonal wetlands, vernal pools, riparian corridors, native grasslands, and developed agricultural lands. Published reports provide variable estimates of wetland habitats. Merced Special Services, Inc. 1993 provided an estimate of 116,509 acres of wetland habitat in the study area. Other estimates including those from the San Joaquin Valley Drainage Program include areas of seasonal and permanent wetlands. These estimates sum to 91,465 acres but do not include the habitats in the East Grasslands. (Table 1). Earlier reports (Table 1) suggest that over 90% of wetland habitats exhibit seasonal hydrology. This complex of wetland habitats is of special significance because the size, juxtaposition, and connectivity of the different wetland types provide a unique opportunity to sustain native migratory and resident wildlife populations. The associated uplands surrounding the semi-permanent wetlands also are of special importance because they provide nesting

Table 1. Estimated area of wetland habitat (San Joaquin Valley Drainage Program 1990) within the Grasslands Study Area.

	Wetland type	Acre
Grassland Water District	Seasonal	32,000
	Permanent	6,400
	Total	38,400
San Luis National Wildlife Refuge	Seasonal	2,665
	Permanent	40
	Total	2,705
Merced National Wildlife Refuge	Seasonal	725
	Permanent	21
	Total	746
Volta Wildlife Area	Seasonal	2,400
	Permanent	300
	Total	2,700
Los Banos Wildlife Area	Seasonal	3,060
	Permanent	760
	Total	3,820
Duck Clubs outside Grassland Water District	Seasonal	11,144
	Permanent	0
	Total	11,144
TOTAL	Seasonal	83,944
	Permanent	7,521
	Total	91,465

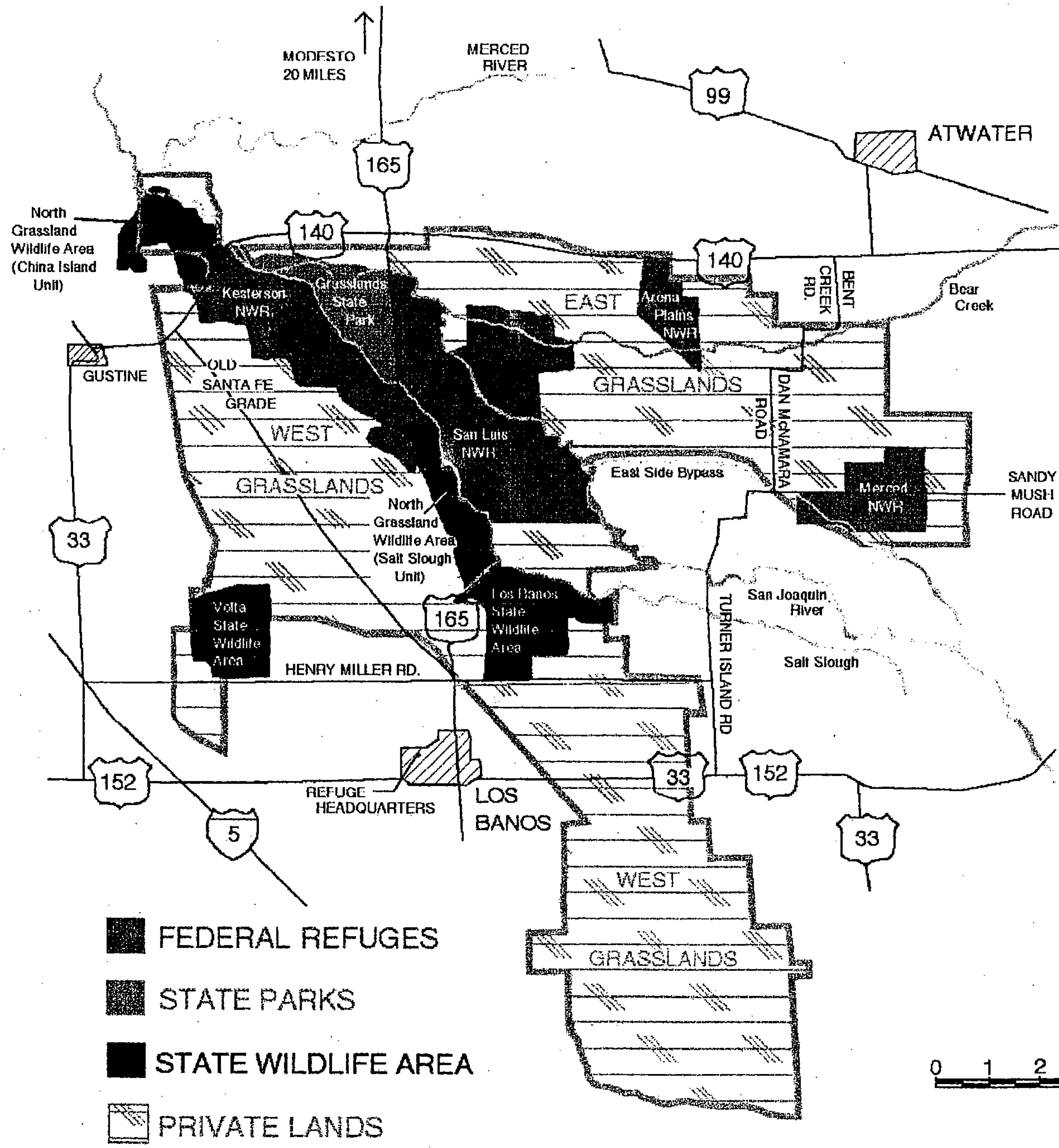

Fig. 3. Federal, State and private owned lands in the Grasslands area.

areas for waterbirds, important food sources for grazers such as geese, and essential habitat for endangered species as well as numerous upland wildlife.

The Grasslands are bounded by numerous towns and cities (Fig. 1). The largest population centers are Merced to the east and Los Banos to the west, with 1990 populations of 50,000 and 13,500, respectively. Smaller communities include Volta, Santa Nella, and Gustine to the west, Stevinson to the north, and El Nido, Dos Palos and South Dos Palos to the east. The 1990

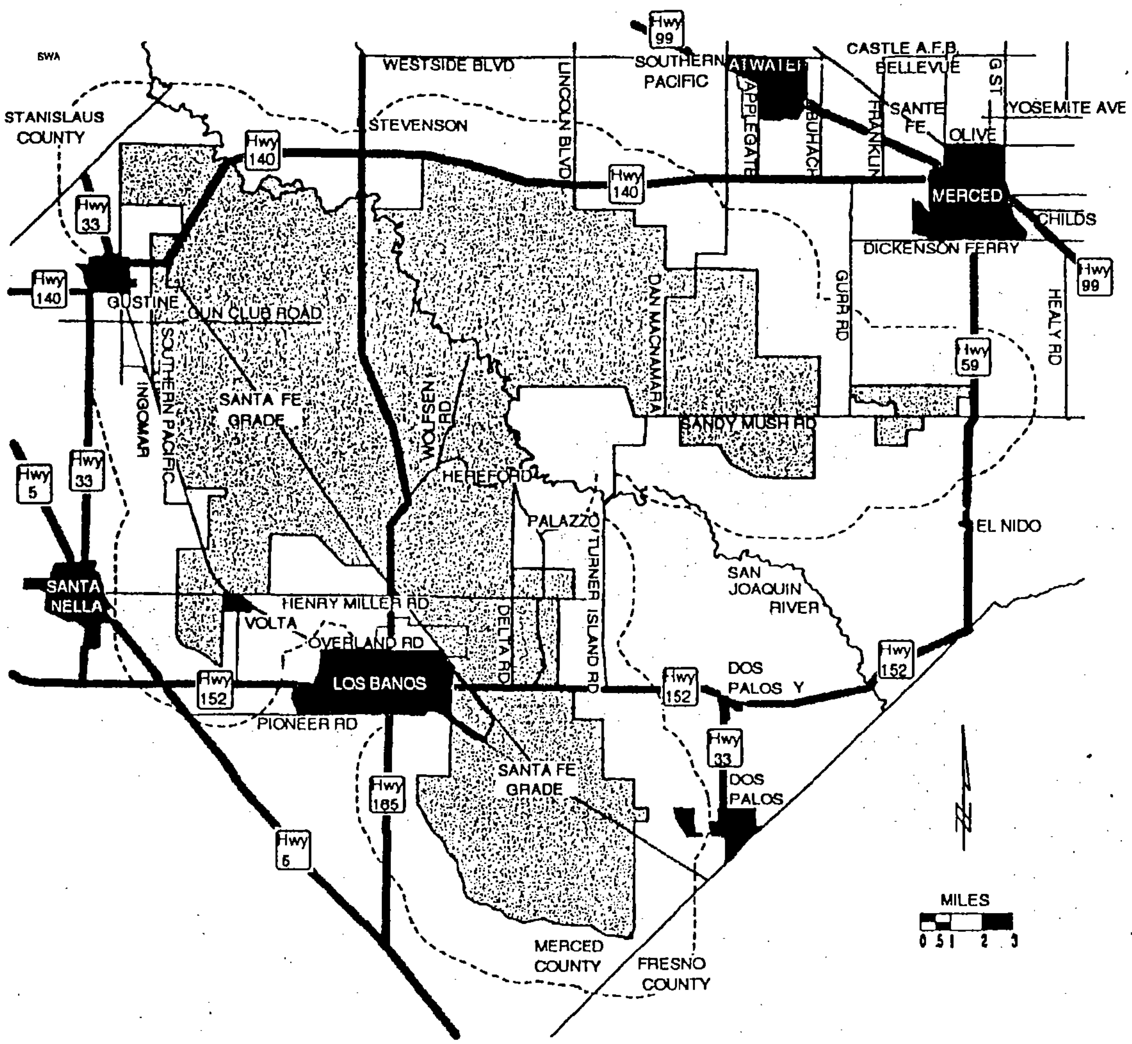

Fig. 4. The location of major roads and highways within the Grassland Study Area of western Merced County.

population of Merced County was 178,403 (Wright 1993) with a projected growth to 264,000 by 2005 (Association of Bay Area Governments 1991). Population projections by the Department of Finance suggest that Merced County will have a population of 626,900 by 2040 (State of California 1993).

Other important features in relation to land use are roads and highways (Fig. 4). Four-lane highways are Interstate 5 to the west, California 99 to the east, and California 152 that runs through Los Banos and bisects the Grasslands into areas described as the North and South Grasslands. Other major state highways impacting the study area include California 140 to the north, California 165 that bisects the area north of Los Banos, and California 33 to the west. Other transportation corridors such as Henry Miller Road also support a considerable amount of local traffic within the study area.

Developments for water transport are key components that influence habitat type, hydrology, and land use in the Grasslands. The area is laced with canals that transport irrigation water or collect irrigation drain water. Starting at I-5 and moving east, the primary water conveyance systems within the study area include the California Aqueduct, Delta-Mendota Canal, Outside Canal, Main Canal, San Luis Canal, San Juan Canal and Eastside Bypass (Fig. 5). There are a large number of smaller canals that move water within and adjacent to the study

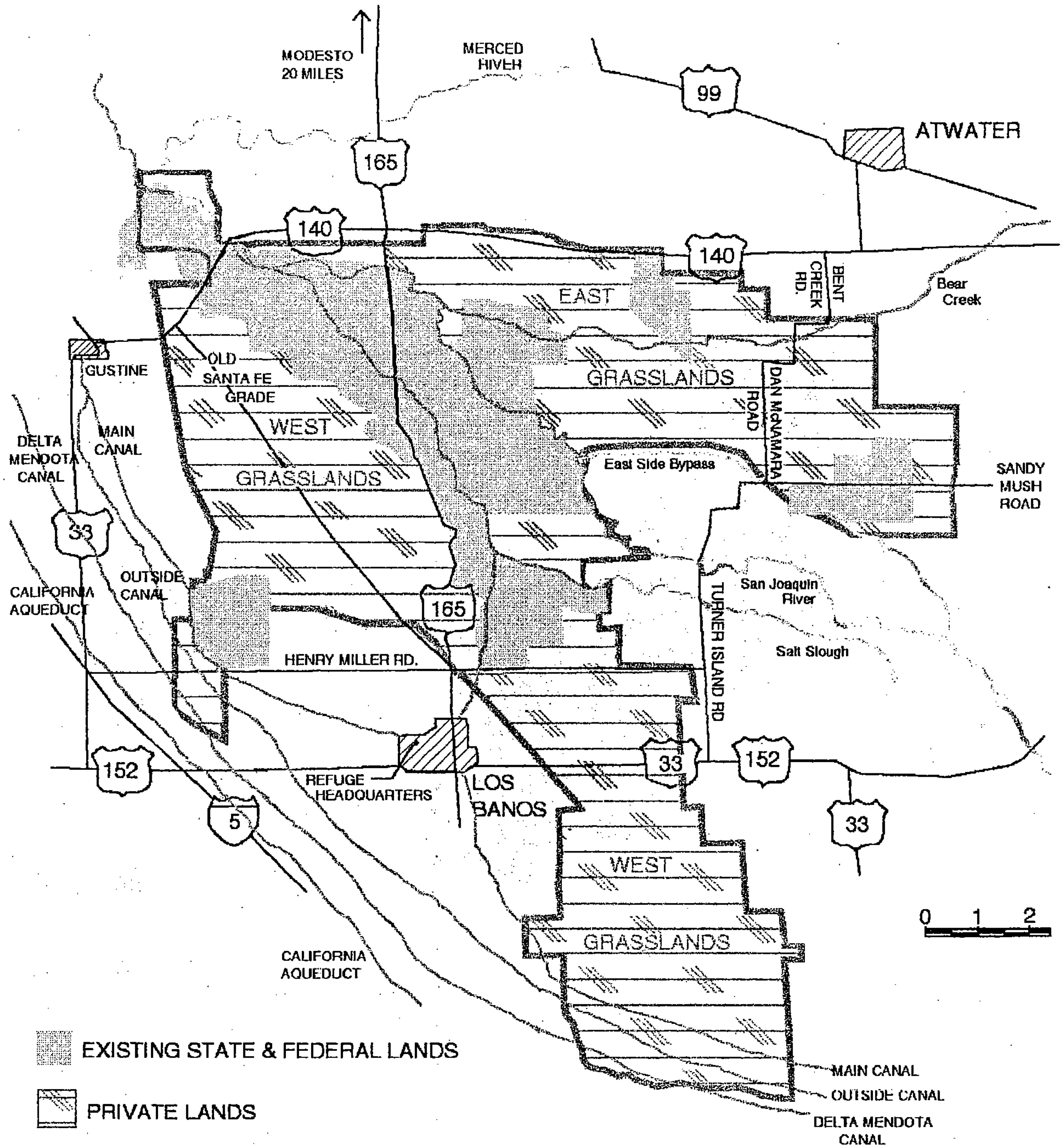

Fig. 5. Location of major water conveyance components effecting the Grasslands Wildlife Management Area.

area (Figs. 6 A and B). In addition, two natural drainages (Mud Slough and Salt Slough) also are used to transport water. These canals have an important influence on the hydrology of the area and, especially for some terrestrial species, represent obstacles for movement.

CLIMATE

The climate of the study area is described as Mediterranean. Distinctly semiarid, the high mountains that enclose the Valley to the east, west, and south, buffer the area from oceanic and continental influences (U.S. Department of

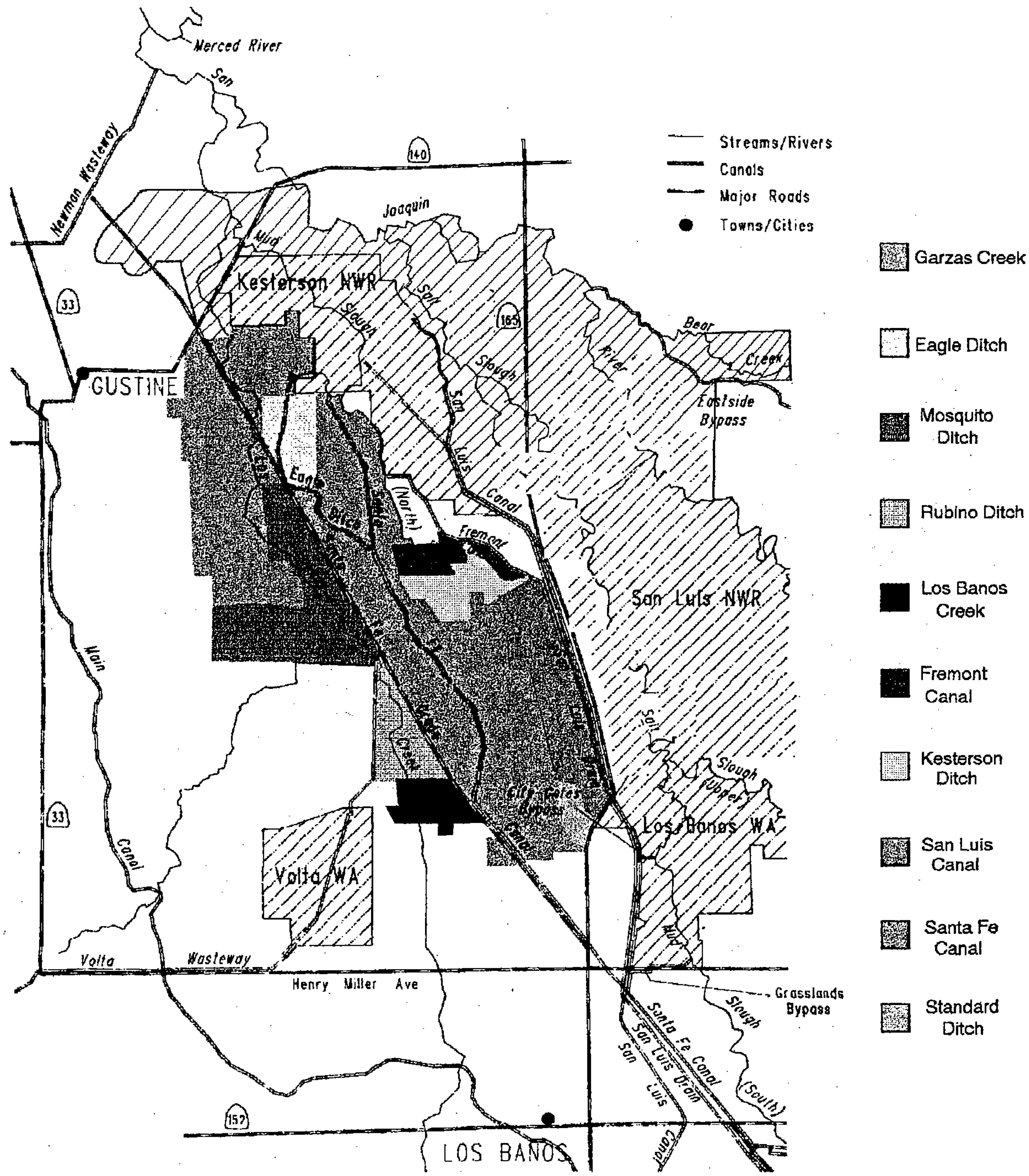

Fig. 6A. Location of water transport canals within the North Grasslands and the areas they supply.

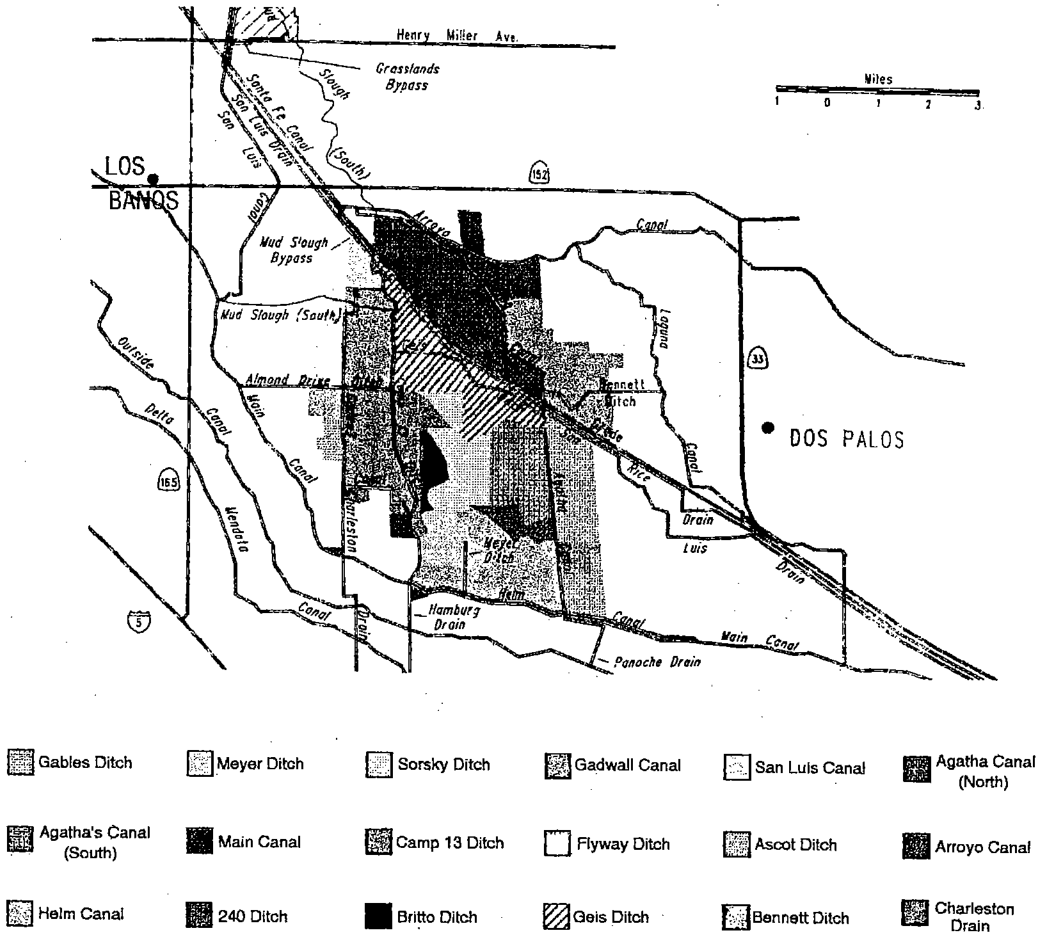

Fig. 6B. Location of water transport canals in the South Grasslands and the areas they supply.

Agriculture 1941, Association of Bay Governments 1991). Summers are long, dry and hot with low relative humidity. During some years the summers are extremely hot. For example, midday temperatures can range from 100 to 110° F, with peaks of 117° F recorded (Nazar 1990). The hottest months are July and August, but clear skies and dry air allow rapid radiation. Thus, night temperatures are frequently 40° F cooler than during the day. This daily variation results in an average summer temperature of only 79° F. Prevailing winds are from the northwest; March is the windiest month. The number of frost free days varies within the study area, ranging from 260 to about 320 days (Nazar 1990).

In contrast, winters are cool and periods of gentle rain, ground fog, and clear frosty weather are common. Winter temperatures average 47.5° F from December through February and the relative humidity is high. Damp, foggy days are interspersed with mild, clear, sunny periods.

Average annual rainfall varies from 8 to 11 inches, depending on location within the study area. However, annual rainfall patterns are erratic and yearly variations of 3 to 24 inches are not uncommon. The rainy period extends from November through April; January is the month of maximum rainfall. Some showers occur in May and in the latter part of September, but little rain falls from June through mid-September.

GEOLOGY OF THE REGION

The current topography and soils in the Central Valley result from processes that began about 150 million years ago when the site was covered by a shallow sea. The North American Plate began to move westward at a faster rate and collided with the diving Pacific Plate. Surface material on the ocean floor was scraped off onto the leading edge of the North American Plate, then folded and pushed upward, possibly as high as 15,000 feet to form what would become the Sierra Nevada mountain range (Whitney 1979). The enormous heat and pressure of these processes changed the sedimentary rock to metamorphic rock present in the Sierra Nevada today. Magma formed along the diving plate and either erupted from onshore volcanoes or cooled within the earth. These processes formed the granitic core of the pre-Sierra Nevada. Activity subsided in the region as the North American Continent pushed the Pacific Plate boundary further westward. The pre-Sierra Nevada mountains then went through an erosional phase in which they were reduced to a gently rolling topography. The granitic core, as well as portions of the metamorphic formations, was exposed on the surface (Ogden 1988). The current Valley floor was originally the site of deposition for chemical precipitates and clastic materials from the ocean. This depositional phase was followed by a downwarping of the ocean floor. Subsequently, thousands of feet of sands, gravel and volcanic materials were deposited in the structural trough that is now the Central Valley floor.

Different geologic processes at different locations in the Valley largely determine present day topographic and soil characteristics. On the west side of the Valley, marine shales were deposited. The Coast Range sediments formed when these deposits were uplifted. The erosion from this uplift created landforms such as the Panoche Pan. Materials from these marine deposits contributed salts, selenium and other potentially toxic substances to the Valley Floor (U.S. Department of the Interior and California Resources Agency 1990).

The dominant landform on the east side of the Valley is the Sierra Nevada Mountains. The eroded material from these mountains is much different from the Coast Range because of the supply of metamorphic and granitic materials throughout the Sierra Nevada. On the east side of the San Joaquin River about 85 percent of the parent material in the Merced area is alluvial material washed from the Sierra Nevada (Arkley 1990). The alluvium varies considerably in mineral composition and in manner of deposition. Some are fresh, unweathered deposits whereas other soils have been developing for thousands of years. Fine silt and clay are dominant in the lower basin area and some soils are strongly alkaline.

SOILS

Soils in the West Grasslands, including the basin, on the basin rim, and on alluvial fans consist of the following: Ediminster-Dospalos-Kesterson nearest the river in the northern part of the Grasslands, Bolfar-Dospalos-Alros along the river to the south, Triangle-Turlock-Britto at the next highest elevation along the river, and finally a bit farther from the river are Pedcat-Marcuse-Volta soils. (Nazar 1990, Fig. 7). Soils on alluvial fans of the San Joaquin Valley are Dosamigos-Deldota-Chateau, and Woo-Stanislaus, but only small areas of these soil types occur within the study area. All of these soils are very poorly drained or poorly drained except for the Woo-Stanislaus soils (Table 2).

Soils in the east Grasslands are very different from those in the west Grasslands largely because of differences in parent material (Fig. 8). These soils fall into two distinct groups and include soils of alluvial fans and floodplains (Merced-Temple-Columbia immediately adjacent to the river and Hilmar-Delhi-Dello along Highway 140 in the north). Poorly drained soils of the saline-alkali basin are Rossi-Waukena, Lewis-Landlow-Burchell, and Fresno-Traver (Fig 8).

HYDROLOGY

Historically the hydrology of wetlands associated with the Grasslands of western Merced County was dynamic, being driven by local and regional precipitation fluxes (Ogden 1988, San Joaquin Valley Drainage Program 1990). Local precipitation occurred as rainfall, which directly influenced wetland hydrology. In contrast, regional precipitation patterns primarily were determined by precipitation events in the surrounding mountains. Melt waters from snow in the Sierra Nevada were particularly important. Regional precipitation patterns influenced the hydrology of the San Joaquin River and its tributaries, which in turn influenced the hydrology in the floodplain by surface flooding or regulation of the water table (Ogden 1988). Thus, both local and regional precipitation patterns interacted to determine the timing, depth, and duration of seasonal flooding that created

Table 2. General characteristics of Grassland soils.

Soil	Location	Description
WEST GRASSLAND SOILS		
Edminster-Dospalos-Kesterson	West of and immediately adjacent to San Joaquin River; In the valley basin	Very deep, nearly level, poorly drained soils that have hummocky microrelief
Bolfor-Dospalos-Alros	West of and immmediately adjacent to San Joaquin River in the valley basin	Very deep, nearly level, very poorly drained soils
Triangle-Turlock-Britto	High zones along west side of San Joaquin River in the valley basin or on the valley basin rim	Very deep, nearly level, very poorly drained soils
Pedcat-Marcuse-Volta	Higher zones away from the west side of the San Joaquin River alluvial rim fans and the valley basin	Deep and very deep, nearly level, poorly drained soils
Dosamigos-Deldota-Chateau	On higher zones away from the west side of the San Joaquin River on low alluvial fans	Very deep, nearly level, poorly drained and somewhat poorly drained soils that are partially drained.
Woo-Stanislaus	On higher zones away from the west side of the San Joaquin River in alluvial fans	Very deep, nearly level, well drained soils
EAST GRASSLAND SOILS		
Merced-Temple-Columbia	Immediately adjacent to east side of San Joaquin River on alluvial fans and floodplains, including natural river levees	Parent material is primarily granitic, water table is near surface; Historically these soils frequently were flooded in early summer for extended periods; Poorly drained
Hilmar-Delhi-Dello	Along Highway 140 east of San Joaquin River on alluvial fans and floodplains	Parent material is granitic alluvial; modified by wind and water level to undulating topography; Permeable to poorly drained
Rossi-Waukena	To East of San Joaquin on higher ground in poorly drained saline-alkali basins	Nearly level soils just above flood level; Parent material is primarily granitic; Poorly drained
Lewis-Landlow-Burchell	East of San Joaquin River on higher ground in poorly drained saline-alkali basin	Parent material is igneous rock nearly level with poor drainage
Fresno-Traver	East of San Joaquin River on higher ground in poorly drained saline-alkali basins	Parent material is granitic; generally level with mounds; Poorly drained

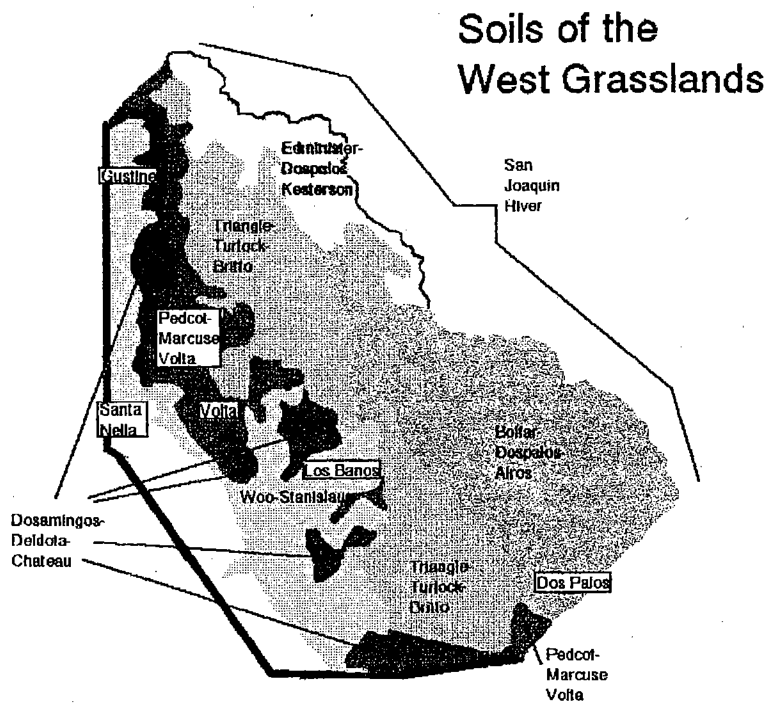

Fig. 7. Soils of the Grassland Study Area, west of the San Joaquin River.

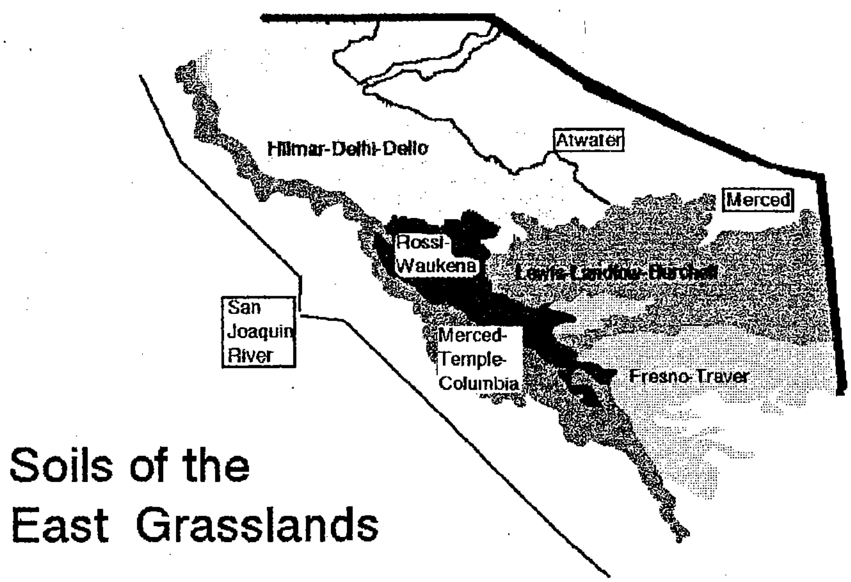

Fig. 8. Soils of the Grassland Study Area, east of the San Joaquin River.

and nourished wetland habitats and provided a haven for myriad wildlife species. Some of the most extensive flooding in the San Joaquin River system occurred when high flows into the Tulare Basin reached levels that caused water to flow northward from this closed basin (Ogden 1988). The natural ridge along the Kings River is at an elevation of 210 ft. msl. Thus, water flows northward when surface water increases above this elevation. Such high flows were recorded in 1862 when Tulare Lake was at 220 ft. msl and likely covered over 500,000 acres with depths up to 40 feet. The normal pattern of precipitation is erratic but the rainy season consistently occurs during winter (November to April). January is the wettest month. This precipitation provides the water supply for the extensive area of vernal pools and seasonal wetlands within the study area. Historically, the tule marshes within the floodplain were replenished with water during the high flows normally associated with melt water from the mountains in spring and early summer. These variable patterns of precipitation and melt water created a dynamic wetland complex with great seasonal and among year variation in number of basins flooded, area of wetlands flooded, and amount and types of foods produced (Ogden 1988). The topography and soils, wetland size, wetland depth, and interconnections with sloughs produced a multitude of different wetland habitats that largely have been disrupted by human activities.

Historically, the value of this wetland system to wildlife was enhanced by its direct connection to other important wetland habitats within the Central Valley of California, including the Delta Region of the San Joaquin and Sacramento rivers, the Sacramento Valley to the north, and the Tulare Basin to the south (Fig. 2). Thus, the Grasslands originally were part of a continuum of wetland habitats extending from the northern sections of the Sacramento Valley to the Tulare Basin. This vast complex of habitats provided myriad opportunities for wildlife to meet life history requirements.

Today, the surface hydrology is driven by flows through man-made canals (Figs. 5 and 6). The water supply primarily enters the Grasslands through a complex water distribution infrastructure. During periods of heavy precipitation and high flows in canals, there is some uncontrolled flooding. The remnant wetlands are flooded during the winter but some areas are flooded in fall to attract early migrant waterbirds. This consistent pattern of early fall flooding of some habitats differs from the historic hydrology of natural flooding during the wet winter period.

Little is known about the historic subsurface hydrology. Currently, the subsurface hydrology reflects the impacts related to water projects and water use by agriculture, municipalities and industry. Undoubtedly, the timing and amount of natural flow in streams of all sizes has influenced discharge and recharge and thus, the current ground water levels. Extraction of ground water for various uses further impacts the ground water reserves. The drainage systems associated with agriculture also have an important influence because water must be transported away from the root zone and these drain waters often carry toxic materials that influence the overall quality of ground water.

HISTORY OF THE GRASSLAND WATER DISTRICT

Much of the current land use in the Grasslands can be traced to the vision of Henry Miller who arrived in the San Joaquin Valley in 1864. Miller's dream was of irrigation (Winton 1962). He saw the potential to capture the annual seasonal flows of the San Joaquin River and use these waters during the dry season to improve agricultural opportunities, including the ability to increase forage production for cattle. Miller and Lux formed a company, Miller and Lux, Incorporated, that was to have a profound influence on wetland and grassland habitats in Merced County. Construction of the first irrigation canal began in 1871 and continued until 1878. Evidence of these early developments designed to irrigate semi-arid pastureland is still evident in the Grasslands and mark the beginning of human efforts to divert water from the western slopes of the Sierra Nevada mountains. Gradually waters from the Kern, Little Kern, Tule, Kaweah, Kings, Fresno, and Chowchilla rivers, as well as run-off from the Coast Range, also were captured for agricultural purposes.

Other entrepreneurs, including James Ben-Haggin and Lloyd Tevis also had an important influence on more southern San Joaquin Valley habitats (Winton 1962). These two men established the Kern Land and Cattle Company that encompassed a large land base, including two-thirds control of the water flow in the Kern River. As Miller and Lux expanded their operations to the south, conflicts developed with the Kern Land and Cattle Company. These conflicts lead to the establishment of Buena Vista Lake in the late 1880's.

A dam was built across the San Joaquin River near Mendota to permit diversion of water to the Grassland region in Merced County. Dikes and levees were constructed at strategic points to allow excess irrigation water from Miller and Lux croplands to be used to flood the Grasslands during periods of adequate water availability. When such diversion occurred in summer and fall, this water provided waterfowl with excellent habitats. Excess water for hunting lands also was furnished by Miller and Lux, but the amount depended on water availability in the San Joaquin and Kings rivers. In dry years, no water was furnished. Miller and Lux, Inc. claimed much of the water the Federal Government needed for the development of the Central Valley Project. The legal battle for water was resolved when the law of riparian rights became the water law of the state of California.

In 1926, Miller and Lux liquidated 98,234 acres in the area now known as the Grasslands (Leach 1960). Lands adjacent to the San Joaquin River were sold to cattlemen, dairymen and duck clubs. When the land was sold, Miller and Lux retained title to the water rights appurtenant to those lands, whether riparian, prescriptive, or appropriative. These water rights were essentially the rights to the San Joaquin River flood waters when the flow of the river exceeded the requirements of the croplands served by Miller and Lux. Even though land owners did not have water rights during this time, excess water was made available to land owners to flood wetlands and grazing lands.

By the 1930's the Federal Government took control of the natural resources of the Central Valley and foremost among these resources was water. The U.S. Bureau of Reclamation and the U.S. Army Corps of Engineers, along with other state and federal agencies, established control of the water, but use for fish and wildlife was not identified until the Central Valley Project was reauthorized in the 1950's.

In 1939, Miller and Lux sold the water rights to the 98,234 acres serviced by San Joaquin River water. The Federal Government paid $2.45 million for these rights and agreed to protect the water right by continued diversion of the water until the United States was ready to use the water elsewhere in the Central Valley. Provision to store these waters was possible with the construction of Friant Dam on the upper reaches of the San Joaquin River. Friant Dam was completed in 1944, but transfer of this water was not possible until completion of the Delta-Mendota Canal in 1952. Various landowners in the Grasslands realized their water supply was about to be cut off following completion of Friant Dam. This stimulated the organization of several livestock and duck hunter associations. On 2 August 1944, all such associations were merged into the Grassland Water Association and incorporated under state laws as a non-profit mutual water association. The original area serviced by the Grassland Water Association was 61,370 acres. Of this area, 53,747 acres either were controlled or owned by 139 duck clubs or livestock companies. Although the primary incentive of livestock companies was beef production, most of these lands were flooded for waterfowl at some time during the year. The number of clubs or livestock companies has varied over the years, but the majority of the land within the Grassland Water District continues to be wetlands that are flooded seasonally each year.

Some important changes also have occurred in the management of Grassland habitats in the past decade. Originally, grazing was an integral part of duck club operations. Grazing for prolonged periods by domestic stock year after year led to some conflicts between beef production and maintaining high quality wetlands for waterfowl and other waterbirds. A dependable water supply always has been a major concern for wetland managers in the Grasslands. As important is the timing of the supply in relation to wildlife need. Recently, legislation (1992 Central Valley Project Improvement Act) has identified the importance of a reliable water supply for maintaining wetland values in the Grasslands. Deliveries of these waters was initiated in 1993. Since then, additional conflicts have developed over the rights to these waters in response to the 1992 legislation.

RATIONAL FOR PRESENTATION OF THIS REPORT

The history of the Grasslands is complex and well-documented, yet confusing to many who have not taken the opportunity to peruse available information. Such confusion results because much of the information is anecdotal or qualitative, rather than quantitative. Thus, there often are discrepancies among published reports concerning the *exact* timing of specific events that have had great significance in understanding the current status of the Grasslands from a natural resources viewpoint. As a result, it is difficult to synthesize this wealth of knowledge in an enlightening manner. This particularly is true when an attempt is made to integrate historical information regarding the main topics of interest, which include (1) the impact that habitat changes have exerted on wildlife populations, (2) the causes of habitat change, and (3) how future changes in the Grasslands ecosystem may further impact plant and animal communities. Fortunately, however, the *chronology* of events relating to a specific topic are consistent. For example, the chronology of habitat change in the Grasslands are equable among documents although specific dates of important events may not coincide exactly. Therefore, it remains possible to use past information to gain valuable insight concerning potential impacts that may result if the Grasslands continue to be modified. The difficulty resides in attempting to combine information relative to human demographics, land use changes, habitat alteration, and wildlife populations into a format that can be understood by individuals with various professional backgrounds and, more importantly, can be used to arrive at decisions that will protect the existing integrity of the Grasslands.

To solve this dilemma, we have taken an approach whereby information for a specific topic will be presented separately at varying scopes. Thus, the history of habitat loss/change will be presented for the Pacific Flyway and continent, the state of California or the Central Valley, and finally the San Joaquin Valley and Grasslands study area. A similar tact will be used to present information on changes in population levels of species. Organization of the information in this format hopefully will serve to identify the importance of scale when evaluating the value of an area. Benefits often are integrally linked to other areas or ecosystems, thereby forcing considerations of the whole (e.g., Pacific Flyway) rather than component parts (e.g., Grasslands). Additionally, valuable insights can be gained by incorporating information or facts from other sources. Although the Grasslands is unique in many ways, some impacts that currently threaten this area have become a reality in other regions of the country. We would be amiss if such lessons were not taken into account. Subsequently, biological information will be presented to more specifically identify the causal agents involved in ecosystem functions and the importance of temporal and spatial aspects of habitats in determining the reproductive success and survival of wildlife.

LEGISLATION OF IMPORTANCE TO LAND-USE IMPACTS IN THE GRASSLANDS

A large number of legislative actions dating back to the early 1800's have had important implications for land use activities in the Grasslands (Table 3). Among the earlier acts of

Table 3. Selected events in wetland and land-use legislation with implications for grassland habitats.

1802	U. S. Army Corps of Engineers created for military and civilian construction works, including navigation.
1849	Swamp Lands Act passed to allow settlement of swamplands with agreement to clear land.
1862	Homestead Act passed to open up western lands to settlement and development.
1877	Desert Lands Act passed to open southwest for settlement.
1886	Green Act permitted levee construction along natural drains to permit reclamation of federal land in the floodplain
1902	Reclamation Act passed giving authority to the U.S. Bureau of Reclamation to develop water supplies for land reclamation and irrigation.
1903	President Roosevelt designates the first national wildlife refuge at Pelican Island, Florida, as a bird sanctuary.
1936	Flood Control Act passed following an earlier version passed in 1927 giving the Army Corps authority for flood control efforts on major streams and appropriating funds for public flood control works.
1948	Water Pollution Act establishes study program and grants for waste treatment.
1950	Dingell-Johnson Act authorized federal aid for restoration of freshwater fish.
1950	President's Water Resources Policy Commission.
1954	Watershed Protection and Flood Prevention Act establishes technical and financial aid to local organizations for watershed work plans.
1954	Public Law 674. Authorized the use of Central Valley Project Water for Fish and Wildlife purposes.
1964	Wilderness Act authorizes reservation of federal lands as wilderness areas.
1968	Wild and Scenic Rivers authorizes reservation of river reaches for preservation.
1969	National Environmental Policy Act requires federal agencies to prepare environmental impact statements on projects and develop mitigation plans with public participation.
1972	Clean Water Act authorizes the Environmental Protection Agency to create and enforce water quality standards and guidelines for permitting draining and filling of wetlands (administered by the Army Corps).
1973	Endangered Species Act authorizes the Fish and Wildlife Service to list threatened and endangered species, to designate critical habitat areas, and to develop recovery plans.
1977	Executive Order 11990 mandating that all federal agencies work to minimize impacts on wetlands.
1978	Fish and Wildlife Improvement Act. Authorized water to be made available for Grassland Water District on a nonreimbursable basis.
1985	Food Security Act establishes the Wetlands Reserve Program administered by the U.S. Dept. Agriculture's Soil Conservation Service to provide funds to farmers who keep wetlands out of production.
1986	Emergency Wetlands Resources Act
1988	The National Wetlands Policy Forum sets a goal of "no net loss" for wetlands and Presidential candidate George Bush endorses the goal.
1990	Water Resources Development Act passed.
1990	Truckee-Carson Water Rights Settlement Act passed authorizing water-rights acquisitons from a Bureau of Reclamation project for the purposes of restoring the Stillwater National Wildlife Refuge wetlands.
1990	Coastal Wetlands Protection, Planning, and Restoration Act authorizes $35 million for wetlands restoration in coastal Louisiana.
1991	National debate erupts over Vice-President Quayle's attempt to change the definition of wetlands used in the 1989 federal wetlands delineation manual thereby potentially excluding from federal protection 50% of the nation's remaining wetlands.
1992	Central Valley Project Improvement Act sets aside 800,000 acre-feet of water for fish and wildlife protection and an additional 430,000 acre-feet of water specifically for wetland use. Also establishes a Restoration Fund with an initial $35 million.

importance were the establishment of the U.S. Army Corps of Engineers, Desert Lands Act, and Reclamation Act which set the stage for changes in natural ecosystems to an agricultural environment. These acts and others also set in motion major changes that led to the destruction and degradation of wetlands, loss of natural habitats and open space, loss of animal populations and plant communities, and changes in hydrology of the San Joaquin Valley.

As natural systems have been lost and degraded there has been a gradual shift in attitudes and legislation to counter earlier programs that exploited systems without consideration for environmental issues (Table 4). Public concern for ecosystems date back to 1891 with the Forest Resources Act which was stimulated by exploitation of timberlands. Water resources were not identified in Federal legislation until 1964 when the Wild and Scenic Rivers Act was passed. Thereafter coastal areas were protected under the Marine Protection and Sanctuaries Act of 1972. Most recently wetlands have been identified as systems holding high public value and legislation such as the Emergency Wetlands Resources Act of 1986 and Coastal Wetlands Protection, Planning, and Restoration Act of 1990 (which protect Louisiana coastal habitats) have been important. Among the most important acts affecting the San Joaquin Valley, including the Grasslands study area, is the 1992 Central Valley Project Improvement Act which set aside 430,000 acre-feet of water for Central Valley wetlands protection and establishes a Restoration Fund with an initial $35 million. Some ecosystem protection also is apparent in some legislation, including the swamp buster provision of the 1985 Food Security Act (Table 3).

Although the purpose of legislation is to establish standards and guidelines for the protection, regulation, and management of natural resources, the types of legislation approved also reflects public attitudes and perceptions regarding wildlife landscapes. In colonial times, some states established game laws in the 1700's to set seasons that provided some annual protection for game species whether they were fish, birds, or mammals (Table 5). The Lacey Act of 1900 was the first protective federal legislation to protect wild animals. The most all-inclusive legislation that protects ecosystems as well as individual species is the National Biological Diversity Conservation and Environmental Research Act of 1990. The passage of such legislation indicates laypersons are becoming increasingly aware that destruction and modification of landscapes may be potentially deleterious to all living organisms, including humans.

Table 4. Evolution of concern for ecosystems in the United States.

Ecosystem	Act
Timberlands	Forest Resources 1891
Grazing Lands	Taylor Grazing 1934
Wildlife Sanctuaries	Fish and Game Sanctuary 1934
Wilderness	Wilderness 1964
Rivers	Wild and Scenic Rivers 1964
Coastal Areas	Marine Protection and Sanctuaries 1972
Forest Lands	National Forest Management 1976
Rangelands	Federal Land Management and Policy 1976
Wetlands	Emergency Wetlands Resources 1986
	Coastal Wetlands Protection, Planning, and Restoration 1990
All Ecosystems	National Biological Diversity Conservation and Environmental Research 1990

Table 5. Evolution of concern for species groups in the United States.

Species group	Act
Large (Huntable) Mammals	Early State Game Protection
Birds, Fish	Laws (1700's)
Wild Animals	Lacey 1900
Wild Birds	Migratory Bird Treaty 1918
Fish	Fish Restoration and Management 1950
Plants, Animals	Endangered Species 1973
All Species	National Biological Diversity Conservation and Environmental Research 1990